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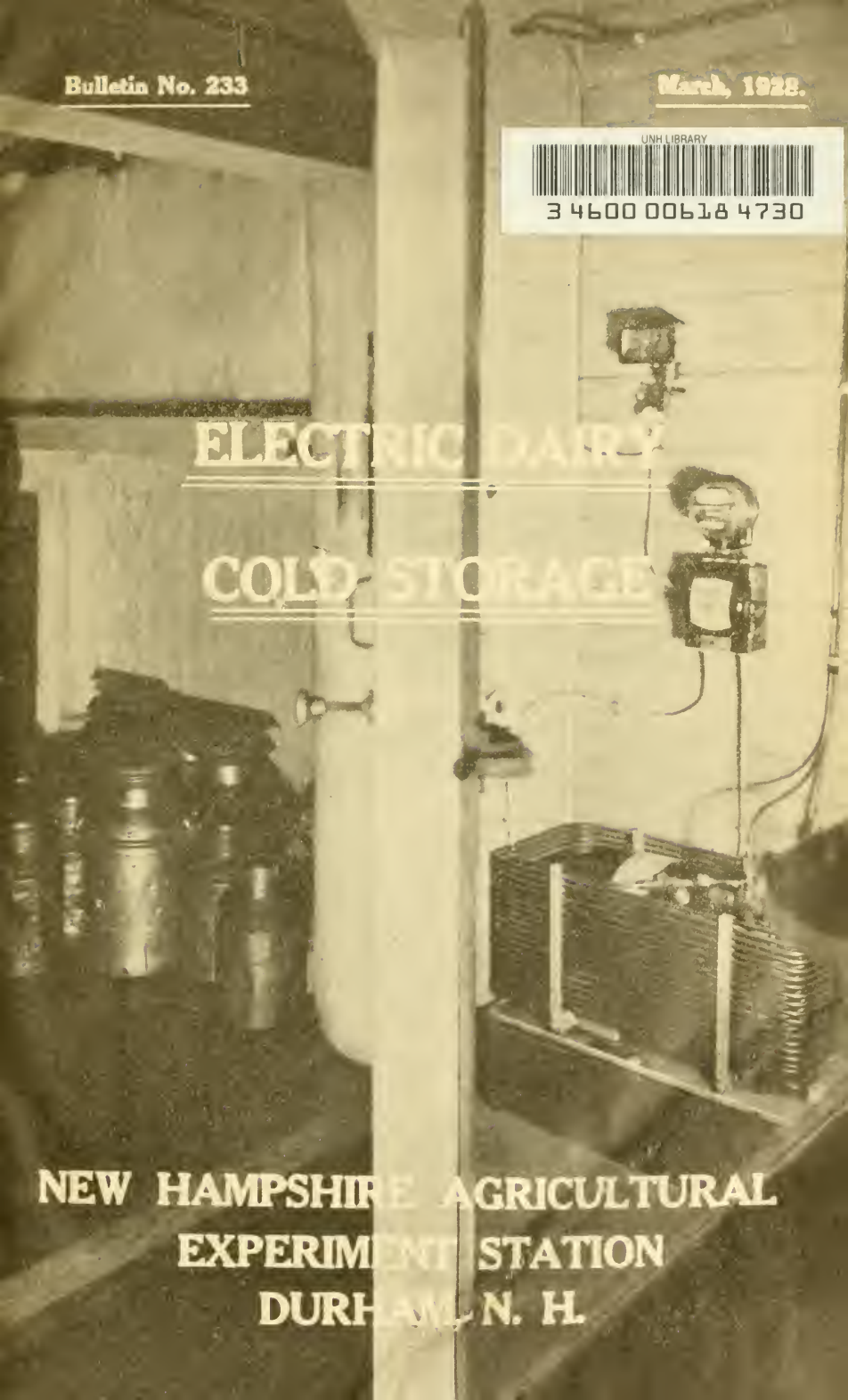

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NEW HAMPSHIRE AGRICULTURAL
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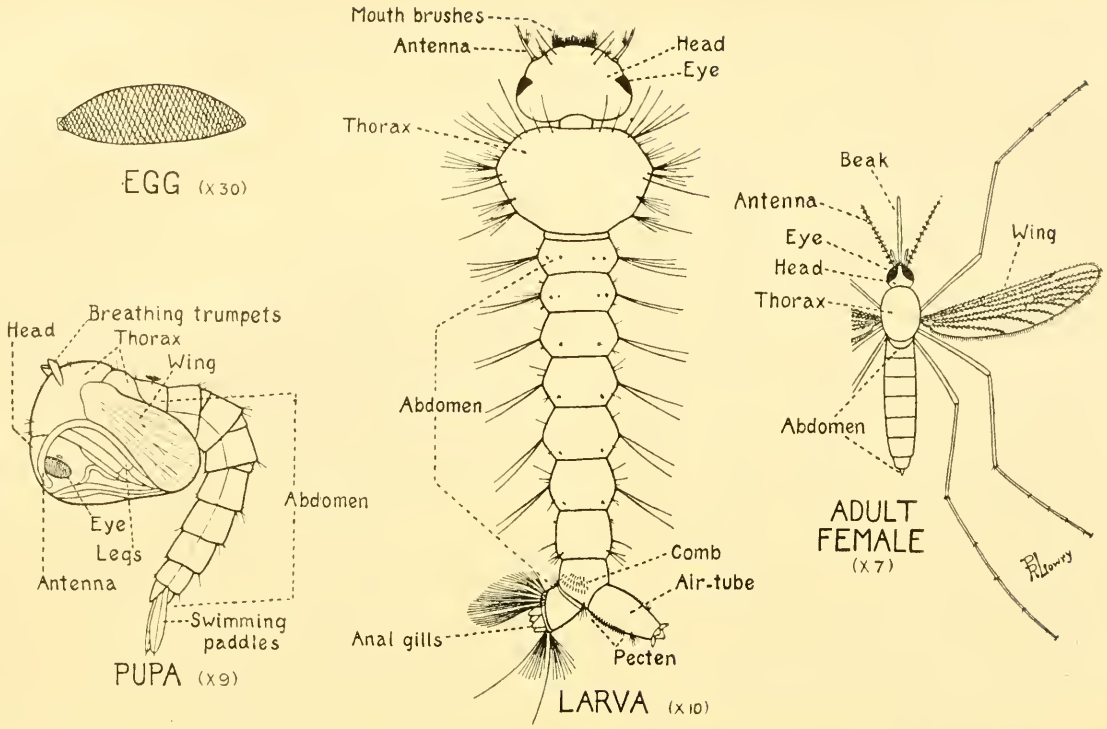
MOSQUITOES OF NEW HAMPSHIRE

A Preliminary Report

By P. R. LOWRY

UNIVERSITY OF NEW HAMPSHIRE
DURHAM, N. H.



The four stages in the life history of the white-marked salt-marsh mosquito (*Aedes sollicitans*).

UNIVERSITY OF NEW HAMPSHIRE
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MOSQUITOES OF NEW HAMPSHIRE

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INTRODUCTION

Mosquitoes are widespread and abundant, except in deserts, from the tropics to the Arctic tundras. Over four hundred different species have been described from North and South America, and many more from other parts of the world. Thirty-eight different kinds of mosquitoes are known to occur in New Hampshire, and eight or ten additional species undoubtedly are present in the state but have not yet been found. Mosquitoes are flies (*Diptera*)and comprise the family *Culicidæ*. The family is divided into two subfamilies. The first, the *Culicinæ,* includes those insects commonly recognized as mosquitoes. Among these are the species discussed in this paper. The second, the *Corethrinæ,* do not bite or suck blood and will not be mentioned here except under the heading Natural Control and in the list of species. Seven of our known New Hampshire mosquitoes belong to this last subfamily.

Scientific names are used because it is practically impossible for the layman to distinguish the different species, and most of them have no common name. Where common names have been applied, these also are used.

The following discussion, except when definitely stated otherwise, applies only to mosquitoes of the subfamily *Culicinæ* found, or likely to be found, in New Hampshire; and although most of the statements hold true for mosquitoes in general, yet exceptions and many additional facts are known concerning the mosquitoes of other regions.

ECONOMIC IMPORTANCE

Mosquitoes are generally recognized as pests because of the irritating effects of their bites. When they are abundant, life may be made almost unendurable by their attacks, and certainly the enjoyment of the infested locality is reduced seriously. In various parts of the country large numbers of mosquitoes have been accused of interfering with construction work, agricultural labor, and other outdoor occupations, of reducing the value of real estate, both farm and town, and of retarding the development of hotels, parks and summer resorts.

Domestic animals may be seriously affected by mosquitoes. Heavy infestation may cause nervousness, loss of flesh, and decreased vitality and resistance to disease. Even death has been reported in a number of cases. A reduction of milk flow in dairy cows, and even of egg production in poultry, has been noted when mosquitoes were present in large numbers.

Only since 1898 have mosquitoes been recognized as carriers of human disease. In that year Maj. Ronald Ross proved the transmission of ma-

laria by anopheline mosquitoes. In 1900 the American Yellow Fever Commission (Drs. Reed, Carroll, Lazear and Agramonte) demonstrated the transmission of yellow fever by the yellow-fever mosquito.

Four diseases are known to be transmitted from one human to another by mosquitoes, and these diseases can be contracted in no other way. The mosquito must first bite a person having the disease, and then later, upon biting a healthy person, may give the latter the disease. Malaria fever (ague, chills and fever) is transmitted by many species of the genus *Anopheles*. Included under this are three kinds of malaria fever which will not be differentiated in this paper. Yellow fever is transmitted by the yellow-fever mosquito (*Aedes ægypti L.*). Dengue fever (breakbone fever) is transmitted by *Culex quinquefasciatus* Say and *Aedes ægypti*. Filariasis (elephantiasis) is transmitted by *Culex quinquefasciatus*.

These are tropical or sub-tropical diseases, the last three of which are never found in New Hampshire, because the mosquitoes carrying them do not occur in the state. Malaria is an extremely rare disease in New Hampshire. Dr. Charles Duncan of the State Board of Health writes: "As far as my knowledge goes, for the last twenty-five years no diagnosis of malaria has been made or confirmed by the Department laboratory. Physicians will occasionally send a blood sample with diagnosis of chronic malaria, but the laboratory has never been able to prove it." The organisms causing malaria are often very difficult to find in the blood of persons having chronic malaria, and almost impossible if the patient has been treated with quinine. Nevertheless, persons who have contracted the disease elsewhere must occasionally enter the state, and as *Anopheles* mosquitoes are well distributed there is the possibility that local outbreaks of malaria may occur.

NEW HAMPSHIRE CONDITIONS

Although we have thirty-eight or more different species of mosquitoes in the state, yet about one-fourth of these never bite humans, and of the remainder, only eight or ten may be considered general pests. The common mosquito pests, in any particular locality during a summer, will generally consist of not more than five or six different species. These important species will vary from year to year, depending on local breeding conditions, climate, and other factors. Many of our mosquitoes occur in abundance only rarely or in restricted localities. The greater part of the field studies that are the basis of this report have been made in Rye and the neighboring coast towns, where mosquitoes are more abundant than elsewhere in New Hampshire. Only incidental observations have been made in other parts of the state.

In Rye, in the summer of 1928, five species occured in great enough numbers to be considered pests. From the middle of May *Aedes communis* and *Aedes excrucians* were not uncommon in the wooded areas. They bred in the early spring pools in woodland and swamp and were present for about two months. They generally remained in the woods

and although they would bite persons entering the woods in the daytime, they were more active at dusk when they were found flying about gardens and porches. The first of June *Aedes vexans* began to appear from the grassy fresh water pools along the coast road. This species was common up to about July 25. None were found after August 5. Its habits were much like those of the first two species.

Although the above three species were common, they were soon surpassed in numbers by the following two which bred in the salt marshes. The brown salt-marsh mosquito (*Aedes cantator*) began to appear early in June. The first adult was noted June 2, and three days later great numbers were found over the marshes. Within a few days these had spead over all the area, and this was the most abundant mosquito up to about the middle of July, and was present in considerable numbers until October. This species hides during the day in shrubbery or long grass, but will bite readily if disturbed. It flies at dusk, is a persistent and vicious biter, and enters houses freely.

The first adult of the white-marked salt-marsh mosquito (*Aedes sollicitans*) was collected June 11, when it was not uncommon on the marshes, and by June 15 it had spread over the entire area. It increased in numbers until the middle of July, when it became the dominant form, far outnumbering all the others combined. It remained abundant until killed by frost, the last collection being made Oct. 22, when it was still common. This is the worst mosquito pest along our coast. It occurred in all kinds of situations, but was least common in thick pine woods. It was found even in the short grass on the fairways of the golf course and was the species that appeared in swarms along the open beaches at dusk. It was not so active during the day as in the evening, but would bite freely and viciously both by day and night, and readily entered houses. The bite of this species causes a more intense burning and tingling sensation than any other we have met.

Conditions in the other coast towns were very similar, at least in respect to the salt-marsh mosquitoes. *Psorophora ciliata, Aedes trichurus, Aedes stimulans* and *Anopheles punctipennis* have also been collected in the coast towns, but were not common enough to be of any importance.

In the greater part of the state, not adjacent to the sea, the principal mosquito pests are the early spring *Aedes*. These appear in May and the adults fly for two months or more. Most of them are woods mosquitoes, but some are found in the open and a few will enter houses. The common species vary with the locality and season, but the following are probably the most important: *Aedes intrudens, Aedes communis, Aedes trichurus, Aedes canadensis, Aedes excrucians, Aedes stimulans,* and *Aedes vexans. Mansonia perturbans* and *Culex pipiens* may also be of importance. The salt-marsh mosquitoes may fly inland for considerable distances, flights of forty miles having been recorded in New Jersey. Our only record of long flight is a female white-marked salt-marsh mosquito collected at Epping Aug. 22, about seven miles from the nearest breeding place.

THE ADULT MOSQUITO

The adult female mosquito is the form familiar to everyone because of its biting and blood-sucking habits. It is a slender, long-legged insect, varying from three twenty-fifths to two-fifths of an inch in length. It is covered with scales and hairs which give the color pattern, the colors being shades of black, gray, brown, yellow, white and sometimes metallic gold, silver or blue. The single pair of wings have similar scales on their margins and along the veins. The males are very similar to the females except that they are somewhat slenderer, have more hairy antennæ, and the mouthparts are different and not suited for biting. From the fact that the males are incapable of piercing the skin and sucking blood, it follows that they are not attracted to humans and are, therefore, seldom seen, unless special search is made for them.

The mouthparts of the female form a beak projecting from the head. The part of the beak normally visible is really a tube which contains the piercing lancets. This tube is slit lengthwise along its upper surface, and does not enter the skin during the act of biting. When the female desires to feed, the tip of the beak is placed on the skin and the lancets forced in. As they penetrate, the beak bends at about its middle, allowing the lancets to escape through the slit, except at the tip of the beak which acts as a guide for them. This permits the head to approach nearer the surface, forcing the piercing parts more deeply into the skin. After the lancets are satisfactorily inserted, blood is sucked out through a tube formed by the lancets. The irritation from a mosquito bite is caused by the injection, during the insertion of the lancets, of certain substances into the wound which produce the swelling, burning and itching. The function of these substances is to prevent coagulation of the blood and so to facilitate feeding. The effect of the bite varies for different species of mosquito, and the susceptibility of different persons to the bite of the same species also varies.

The females of most of our New Hampshire mosquitoes are blood-suckers, though they vary considerably in the eagerness with which they seek to bite. Some species are extremely bloodthirsty and will attack quickly and fearlessly, while others are slow to attack and easily frightened off. Nearly all of the blood-sucking species will attack man, but a number of them seem to prefer the larger mammals such as horses or cows, and one species is known to attack only cold-blooded animals such as frogs. All male mosquitoes, and the females of a number of species, feed only on the nectar of flowers and plant juices; these substances may also form a part of the food of the blood-sucking females.

Many mosquitoes hide during the day in sheltered places, such as long grass or shrubbery, becoming active at dusk, but some fly both by day and by night and will bite readily in the daytime, particularly if their haunts are invaded. Some species are found only in the vicinity of their breeding places, others may fly a mile or more from their place of origin, while some of the salt-marsh species sometimes migrate widely.

Only seven or eight of our New Hampshire mosquitoes are commonly found in houses, the others very seldom coming indoors, although some of them may be common in the surrounding fields and gardens, or on porches at night.

The length of life of female mosquitoes may vary from two to six weeks with some species to as much as two months or more with many of our common woods mosquitoes. The males are always short lived.

The breeding place of mosquitoes is dependent on the place which the female selects to lay her eggs. Each species has a preference for a certain type of locality for egg deposition, and most of the eggs are deposited in such preferred locations. If the desired type of pool is absent, or occasionally for some other reason, the females may deposit eggs in unusual situations.

THE EGG

The eggs of mosquitoes are small, elongate, more or less cylindrical and tapering to one or both ends. The eggs are white when first laid, but the color soon changes to brown or black. The shell usually bears raised lines on its surface, which form a reticulate or lattice-like pattern.

Some mosquitoes lay their eggs singly or in small, loose groups, while others fasten their eggs together in masses. In the latter case the eggs taper toward one end, are deposited in an upright position with the larger end down, and are glued together with a secretion which hardens on contact with the air. The shape of the eggs tends to give the mass a slight curve or convexity on the bottom. Such egg-masses are called egg-rafts. The place of egg deposition varies with different species of mosquitoes. Eggs may be laid on the surface of water, on the sides of the container above the water, or on sod, mud, dead leaves, etc., in depressions or moist areas that are likely to be filled with water.

The length of the egg stage depends on the temperature, on rainfall, floods or tides, and on the type of life history. In mosquitoes which lay eggs on the surface of water, the egg-stage is often entirely dependent on temperature; the higher the temperature the shorter the egg stage. Under ideal conditions the period from the laying of the egg to its hatching may be less than twenty-four hours. When the eggs are laid in dry depressions, they will not hatch until rains, floods or tides fill these hollows and cover the eggs with water. The eggs may lie unhatched for long periods, but after being covered with water they may hatch in less than an hour. If the depression should fail to be filled with water one year, the eggs may possibly lie over and hatch the following year, although it is not known certainly how long they will retain their vitality. Many of our New Hampshire mosquitoes have but a single generation each year, and the eggs of these, irrespective of temperature or water conditions, must be frozen before they will hatch. In these last species, the egg stage may be eleven months or longer. The egg stage of the different species of mosquitoes will, therefore, vary from less than a day to over a year, and perhaps longer.

THE LARVA

The larva is the growing stage of the mosquito. During the larval period or larval stages the insect feeds a great part of the time and stores up food for use during the pupal period. When first hatched the larva is very small, but it generally grows quite rapidly. During its growth it moults, or sheds its skin, four times. The larva is often called a wriggler because of its method of swimming backward by whipping the abdomen from side to side.

The larva or wriggler is small and slender in general appearance. The thorax and abdomen vary from dirty white or yellow to light gray or pale brown in color. The head, air-tube and part of the ninth abdominal segment are light brown or brown, and the head often has definite markings. The head is distinct and has a pair of black eyes, a pair of short antennæ toward the front of the head, and two thick tufts of hair on the front of the head called the mouth brushes. The thorax is compact, broad and somewhat flattened. The abdomen is slender and elongate, consisting of nine cylindrical segments. On the dorsum, or top, of the eighth segment is a tube used for breathing, called the air-tube. The air-tube varies in length, being long and slender in some species, shorter in others, and very short and stout in *Anopheles*. The larvæ of most species have a row of stout, tooth-like spines along each side of the air-tube called the pecten. On each side of the eighth segment is a group of large spines called the lateral comb. In *Anopheles* each comb is replaced by a single, large, toothed plate called the lateral plate. Projecting from the tip of the ninth abdominal segment are four fragile, leaf-like appendages, the anal gills. Near the gills is a thick tuft of long hairs. Single hairs or tufts of hairs are scattered over the larva.

The larvæ of all mosquitoes breed in standing water. A few species are known to breed also in the slow-flowing, vegetation-choked backwaters of streams, but we have never found larvæ in these places in New Hampshire. The breeding places of mosquitoes vary considerably and are dependent on the location chosen by the female for egg-laying. Some mosquitoes prefer open, sunny pools, some shady pools in wooded regions. Some are never found far from the salt-marshes of the seacoast, while others have very specialized breeding places. Clean water is required by some species, many can use dirty water, while a few actually prefer foul water for breeding. Permanent or semi-permanent bodies of water, as swamps, the vegetation-choked borders of lakes, springs, and bog pools, are preferred by some species, but the majority of New Hampshire mosquitoes breed in temporary collections of water formed by melting snow, heavy rains, or floods. The salt-marsh mosquitoes breed only in the pools on the salt marshes filled by high tides or heavy rains. A few species are more or less domesticated, breeding primarily about houses in collections of water in rain-barrels, empty cans, bottles, etc. The pitcher-plant, rock-pool, and tree-hole mosquitoes breed only in these specialized locations, from which they take their names. The preferred breeding place of each mosquito is given in the

list of species, although many of them may occasionally be found breeding in other types of pools.

Most mosquito larvæ feed on organic matter, principally the microscopic plants and animals, both living and dead, which live in water. These tiny organisms form a scum on the surface of standing water and collect as an ooze on the bottom of the pool and over the plants growing in the water. The larvæ sweep this ooze or scum into their mouths by means of the mouth brushes. Nearly all of our mosquito larvæ are bottom feeders, but some of them will feed occasionally at the surface, and *Anopheles* always feeds on the surface scum. The larva of one New Hampshire mosquito (*Psorophora*) is predaceous, feeding on the larvæ of other mosquitoes.

It is necessary for most mosquito larvæ to come to the surface to breathe. The tip of the air-tube is thrust through the surface film, and air is taken in through the tube. By means of an apparatus on the tip of the air-tube the larva is able to hang motionless at the surface, suspended from the surface film. Most larvæ hang at the surface with the body at an angle, but *Anopheles* lies parallel with and close to the surface film. The anal gills assist in breathing while the larva is under the water.

The length of time the larva can remain under water varies with the different species. A few rare or non-biting species seem to be able to breathe entirely by means of the anal gills, seldom or never coming to the surface for air. One species (*Mansonia*) breathes by thrusting its pointed air-tube into the roots of sedges growing in the water and obtaining air from the plant tissues. It remains attached and never comes to the surface.

The length of the larval period is dependent on temperature, food supply, and the life cycle. Most mosquitoes have a short larval period, varying from six or seven days to several weeks. In general the higher the temperature and the more abundant the food, the shorter is the larval period. In those species hibernating as larvæ the overwintering larvæ may live for several months. One of these which has but a single generation each year may have a larval period of over eleven months.

When the larva is full grown, and at the time of the fourth moult, it transforms to the pupa. Changes go on for some time in the larva, and when it sheds its skin for the last time the pupa emerges fully formed.

THE PUPA

The pupa is the transforming stage of mosquitoes. During this period the insect goes through the complicated process which changes it from the worm-like larva to the adult mosquito. The pupa does not feed, but subsists on the food stored up by the larva. It differs from the pupa of most insects in being active, and is often called a tumbler from its habit of swimming end over end.

All mosquito pupæ are brown in color and somewhat resemble a large comma in shape. The head and thorax are grown together to form a

compact mass. Two short tubes extend up from the upper side of the thorax. These are the air-tubes or breathing-trumpets. Extending from the thorax is the slender, curved abdomen composed of nine segments. At the end of the abdomen on the eighth segment are two thin, leaf-like appendages called the swimming-paddles. Through the body wall of the pupa can be seen traces of the adult organs (eyes, wings, legs, etc.) which are rapidly developing.

The pupa breathes at the surface by means of the breathing trumpets. It is lighter than water and floats to the surface when at rest. In order to remain at the bottom the pupa swims under plants or debris which hold it down. A single species (*Mansonia*) does not come to the surface but obtains air from water plants by thrusting the breathing trumpets into the roots.

The pupal period is short, generally varying from one day to about a week. Its length is dependent on temperature; the higher the temperature the shorter the pupal period.

When the pupa is fully developed it floats at the surface and gradually pumps air into the pupal skin until the pressure splits it down the back. The adult mosquito, which has formed inside the pupal skin, then works its way out and rests on the empty skin or climbs upon some support above the water. The newly emerged adult is soft and white in color, but in the course of a few hours the body hardens, the wings expand and the normal color is assumed.

LIFE HISTORY

All mosquitoes go through the four different stages described above, *i.e.*, egg, larva, pupa, and adult. The period from the egg to the adult is called a generation or a brood. A generation begins with the laying of the egg by the adult mosquito. From the egg hatches the larva, which feeds and grows, moulting, or shedding its skin, four times during growth. After the larva is full grown, and at the time of the fourth moult, it transforms to the pupa. Great changes occur in the insect during the pupal period, and when these are completed, the pupal skin is split and the adult mosquito emerges. After a varying period, during which mating occurs, the females lay eggs for a new generation. If these four stages are completed but once each year, the mosquito is said to have one generation or brood, if twice a year, two generations, etc. The generations and changes which an insect passes through in a single year are called its life history.

New Hampshire mosquitoes have several types of life history, examples of which are briefly outlined in the following paragraphs.

Most of our common woods mosquitoes (*Aedes*) have a single generation a year. The winter is spent in the egg stage, and the larvæ hatch in the spring in the early pools formed by melting snow and spring rains. The adults emerge in May and deposit their eggs on sod, mud or dead leaves in depressions or moist areas where water is likely to collect. The eggs will not hatch until the following spring, even though

covered by water, because they must be frozen before hatching can take place. The adult females may live for two months or more.

A variation of this type of life history occurs in a few species where all the overwintering eggs do not hatch when first covered with water, but some hatch each time the pools are filled by rains during the summer. In these species there appear to be several generations, when in fact there is only one.

Some mosquitoes, particularly the salt-marsh mosquitoes, winter in the egg stage, but have several generations each year. The eggs are laid on sod or mud in depressions, and the number of generations depends on the weather; that is, the eggs hatch whenever the depressions are filled by heavy rains or extra high tides.

A number of our species (*Culex*, *Anopheles*, *Uranotænia*) pass the winter as fertilized, adult females. The eggs are laid directly on the surface of the water. In these mosquitoes breeding is continuous, one generation following another throughout the summer.

Three New Hampshire mosquitoes pass the winter as larvæ (*Mansonia*, *Wyeomyia* and *Culicella melanura*). The eggs are laid on the surface of the water. The first has but one generation, the last two have more than one generation each year.

NATURAL CONTROL

Climate, particularly temperature and rainfall, plays an important part in determining the abundance of mosquitoes. It is often the most important factor in the natural control of mosquitoes breeding in temporary pools and puddles. Low temperatures retard the growth and development of all immature stages, and if there is not abundant moisture the pools may dry up before the adults emerge. High temperatures with little or no rainfall, which dry up pools very rapidly, may kill the mosquitoes before they have completed their development, or may prevent further breeding through lack of suitable pools. During such seasons the total number of mosquitoes will be much reduced. On the other hand, seasons with normal or high temperatures and abundant and frequent rainfall will result in great numbers of mosquitoes, for the maximum number of breeding places will be available. Such unusual seasons may even permit some breeding in drained or ditched areas.

Many animals are known to feed on mosquitoes, some having no other food. These natural enemies are very seldom able to control the pests completely because of the short life history of mosquitoes, the varied and specialized breeding places, and the high rate of reproduction. They do, however, materially reduce the numbers of mosquitoes and under certain conditions may constitute an efficient control.

Bats will eat mosquitoes but they prefer larger insects. Certain birds are known to feed on them occasionally. The nighthawk, the whip-poor-will, the swallows, and the flycatchers sometimes catch the adults, while some shorebirds and wading birds, as sandpipers and phalaropes, eat the larvæ and pupæ. The principal natural enemies live in the water and

feed on the larvæ and pupæ. Fish and insects are the most important forms and are especially efficient in permanent bodies of water, although the insect enemies also occur commonly in less permanent pools.

Fish are probably the greatest factor in reducing or preventing mosquito breeding in permanent ponds and lakes. No mosquitoes are able to breed in ponds properly stocked with fish except in detached or obstructed pools or vegetation-choked borders and inlets where the fish cannot penetrate. In Rye, in 1928, a series of small, fresh-water pools were under observation, some of which were permanent and others of which dried up during the summer. The permanent pools were well stocked with nine-spined sticklebacks (*Pungitius pungitius L.*) and no mosquitoes bred in these pools, while the temporary pools, in which the fish did not occur, gave rise to swarms of *Aedes vexans*.

The greatest enemy of the salt-marsh mosquitoes, and the only one we have found in New Hampshire, is the killifish (*Fundulus heteroclitus L.*), also known as the killie or mud minnow. This little fish, which never grows longer than four and one-half inches, is extremely abundant in all kinds of salt marshes, and extends up the creeks into brackish or even fresh water. It is found in clean or dirty water, in large pools or the shallowest depressions, in muddy holes and vegetation-choked ditches; in fact it follows the incoming tide anywhere on the marsh where there is water enough for it to push its way through. It has an insatiable appetite for mosquito larvæ and pupæ, and wherever it occurs the mosquitoes are devoured before they can complete their growth. Only in the detached and isolated pools, which are not reached by ordinary tides, can the mosquitoes breed successfully.

All the important insect enemies of mosquitoes live in fresh water, either during the immature stages (larva, nymph, naiad) or during both adult and immature stages. The predaceous diving beetles (*Dytiscidæ*) live in the water in both stages and readily feed on mosquito larvæ. In our observations the larvæ of these beetles, called "water tigers", have been the commonest insect enemy of mosquito larvæ in New Hampshire. The larvæ of the water scavenger beetles (*Hydrophilidæ*) occasionally feed on mosquito larvæ, as do also the nymphs and adults of the black-swimmers (*Notonectidæ*). The naiads of the dragon flies (*Odonata*) will eat larvæ and pupæ of mosquitoes, and the actively flying adults sometimes catch adult mosquitoes.

The larvæ of a number of species of mosquitoes are predaceous, and feed on other mosquito larvæ. *Psorophora ciliata* has this habit, but the species is rare in New Hampshire. The larvæ of the non-biting mosquitoes (Subfamily *Corethrinæ*) are predaceous, feeding exclusively on other mosquito larvæ. They are, however, not especially common, and we have found them only in cool, shady woodland pools. The members of this subfamily found in New Hampshire are given in the list of species at the end of this paper.

CONTROL

Active attempts at mosquito control were first made after certain of these insects had been shown to carry human diseases. Methods for their control have been perfected in the Panama Canal Zone and the southern states. New Jersey was the first state to initiate and carry out control work against the common, non-disease bearing mosquitoes, the investigations beginning in 1900. Other states and the Federal Government have continued this work, until now the adequate control of the mosquito nuisance can be accomplished at a cost well within the reach of most communities.

In the early spring of 1928 the precinct of Rye, N. H., asked the State Experiment Station for recommendations for the control of mosquitoes. A preliminary study was made, and suggestions for control were submitted. In September, 1928, the precinct of Rye appropriated $1500. for mosquito control, and the precinct of North Hampton voted $750 for the same purpose.

Before undertaking control measures for mosquitoes we should know several facts about the locality in order to obtain the best results:

1. What species of mosquitoes are present?
2. When do they occur and what is their relative abundance?
3. Where do they breed?
4. What is the most practical and economical method of controlling or eliminating each breeding place?

General methods may be given for mosquito control, but each locality presents an individual problem, the solving of which depends on the answers to the above questions, and on the amount of money which the locality is prepared to expend on control work. The following pages give a general discussion of the various control measures.

OILING

Oiling is probably the most common and best known method of mosquito control. It is cheap, effective, readily available, and easily applied. It is obvious that more permanent methods, such as filling or draining, are more effective and cheaper in the long run; but for temporary measures or as a supplement to permanent methods, nothing has been found which gives better results than oil. A thin film of oil, spread over the surface of the breeding pools, will kill all larvæ and pupæ that come to the surface to breathe.

The number of treatments necessary to control mosquitoes depends on temperature, rainfall, the kinds of mosquitoes present and their life history. The temporary pools which breed most of our early, one-generation, woods mosquitoes, only need treatment in the spring, after the larvæ have hatched, and before the adults have emerged. If these pools fill up later from heavy rains, additional treatments may be necessary to control other species. For those speecies which breed continuously

during the summer, the breeding pools must be treated every two to four weeks depending on the temperature. For the salt-marsh mosquitoes, the marshes must be inspected after each heavy rain or extra high tide and the pools treated which show breeding.

Many kinds and grades of oil may be used, but to be most effective an oil should spread rapidly, form a complete film over the surface of the water, and not evaporate too quickly. Low-grade kerosene is often used; this spreads and kills well, but evaporates so rapidly that its protective effect is soon lost. A very heavy oil evaporates slowly, but is likely to cling together in spots and not form a complete film. Used crankcase oil may be applied to small areas. This does not spread well, however, and is more efficient if diluted with 25 per cent kerosene. The best type of oil has been found to be the petroleum distillate fuel oils. These spread and kill well and the film lasts for eight or ten days. The New Jersey workers have recommended the following tentative specifications for the most efficient oil of this last type:

Specific gravity	—	32°-37° Bé
Flash point	—	150° F.
Cold test	—	0° F. —pour
Boiling range	—	350°-675° F.
Color	—	Straw to yellow
Viscosity	—	50-100 Sayb/100
Surface tension	—	20 dynes per cm.

There are no oils on the market which meet all these specifications, but there are several which approximate them in most respects and which have given very good results.

The New Jersey workers have also found that the addition of small amounts (0.5%) of coal-tar acids greatly improved the spreading properties of the fuel oil on water covered with vegetation and organic matter. Coal tar or crude cresylic acid containing 95% cresylic acid (Cresol) is mixed with the oil at the rate of one part to two hundred parts of oil. The addition of this unsaturated hydrocarbon reduces the interfacial tension between the water and the oil, thus increasing the spreading.

Most oils used to kill mosquitoes will injure and discolor vegetation. In ornamental pools, where this is not desirable, gasoline may be used. This evaporates very rapidly and the treatment must be repeated whenever breeding is noticed. Stocking such pools with fish is the best method of control.

The oil may be poured on the surface of the water or thrown on with a tin cup, but much better spreading and a saving of materials is obtained by the use of a sprayer giving a fine mist spray. One of the small, portable, compressed-air sprayers is very handy for this work.

FILLING

The filling up of pools, swamps and low areas is a permanent method of eliminating mosquito breeding. The initial cost, though often somewhat high, is the only expense; for such areas, if properly filled, need no future inspection or treatment. Swamps or low areas near towns may often be filled by using them as dumps, oiling the unfilled portion each year until the filling is completed. Care must be taken that cans and other receptacles do not increase the breeding places.

DRAINING

Drainage of swamps, marshes and pools is a permanent method of mosquito control. Periodic inspection is necessary in order to make repairs or to clean out obstructed ditches or drain pipes. In years of greatly excessive rainfall the drainage may be inadequate to carry off the water rapidly enough and some mosquito breeding may occur in drained areas. In such years some oiling may be necessary. The methods used for fresh water areas are similar to those employed in drainage for agricultural or industrial purposes and are well understood.

The drainage of salt marshes is partly an engineering problem, and surveys should be made and the ditches laid out before work is begun. In the open salt marshes which occur in New Hampshire, the object is not to drain them completely, but to open them up so that the normal tides run in and out freely, and no isolated pools hold stagnant water longer than a week. The high-lying or enclosed salt marshes, over which the tide sweeps only occasionally, are the greatest breeders of salt-marsh mosquitoes. Wherever the tide reaches regularly the killifish come with it and devour all larvæ and pupæ.

Mosquitoes do not breed in all parts of every salt marsh, and ditching is only necessary where observation shows that breeding occurs. Salt-marsh draining is accomplished by cutting parallel ditches through the marsh, an average of about 300 linear feet of ditch being required per acre. The ditches are ten inches wide and thirty inches deep, with smooth, perpendicular sides. Ditches twenty-four inches deep may be used in small marshes. No ditch depending on a single outlet should be over one-fourth mile long, and each ditch should have a strong tidal outlet, for the greater the tide sweep the less likely it is to become obstructed.

The ditches are opened, ar far as possible, into the natural creeks; but where this is impossible, large main ditches, thirty inches deep and as wide as necessary, are cut as outlets. Short spur ditches may be run to large isolated pools which do not drain readily. Small pools may be fil'ed with sods taken from the ditches. Special spades are used in cutting the ditches, and for extensive operations power ditchers are often used. The state of New Jersey has done the greatest amount of work in salt marsh drainage, and most of the above information on this subject is taken from the results of their experiments.

FISH

Artificial ponds, and natural ponds and lakes, if necessary, should be stocked with fish which will eat the larvæ and pupæ of mosquitoes. The common goldfish, the silverfish, the fresh-water killifishes, and the top minnows are all useful in stocking water that contains no fish. Natural waters are usually well stocked with various species of fish which will feed on the mosquitoes. In any case it is necessary to clear out the vegetation-choked margins and eliminate or open up isolated pools so that the fish will have free access to all parts of the pond. This treatment is all that is necessary for mosquito control in ponds and lakes if they do not have swamps in connection with them.

SCREENING

Screening houses will exclude most mosquitoes, but must be done thoroughly as these insects are able to enter through very small cracks.

Screens for doors and windows should be made to fit tightly, and the wire should have not less than sixteen meshes to the inch. In some parts of the country beds are provided with canopies of mosquito netting and these are often used in camping. The netting should be free of tears or expanded meshes and large enough so that it can be tucked well under the mattress. Headnets are sometimes worn when fishing or working where mosquitoes are very numerous.

REPELLENTS

Many preparations are on the market, advertised as mosquito repellents. Most of them contain some volatile oil, such as oil of citronella, oil of pennyroyal, or cedar oil. These will help to keep mosquitoes away for a time, but an application is not effective for more than an hour or so. Kerosene extracts of pyrethrum may be used in the same way, and these are also useful as a spray in killing mosquitoes in the house. For the latter purpose, the room should be closed tightly and the material applied with a good atomizer. The walls and ceiling should be covered, the air should be filled with the mist, and special attention should be given to hiding places, such as closets and beneath furniture. The rooms should be kept closed for some time after the treatment.

LIST OF SPECIES

The following list includes all the mosquitoes known to occur in New Hampshire, together with a few that will certainly be found with additional collecting. The general statements made under the genus are characteristics common to all, or nearly all, the species of that genus. Additional information or exceptions to the general statements are given under each species. When a genus has only one representative in the state, all the information is placed under the species.

The author's records are from the southeastern part of the state, the other distribution records being taken mostly from published reports. The late H. G. Dyar, who was our foremost national authority on mosquitoes, has collected in the state, principally at Center Harbor, and many records are taken from his publications. August Busck also collected in the state. C. W. Johnson, of the Boston Society of Natural History, has done much collecting in New Hampshire and has published a "List of the Diptera or Two-winged Flies" of New England which contains many records for New Hampsphire mosquitoes. We are also indebted to Mr. Johnson for permission to examine the mosquitoes in the collection of the Society. Under each species we have given the localities where it has been found, the date collected and the name of the collector. In the case of the three men named above, we have used their initials. Where no collector is given, the record is that of the author. All records are for adult mosquitoes unless otherwise stated.

FAMILY CULICIDAE. The Mosquitoes

SUBFAMILY CULICINAE. The True Mosquitoes

Genus Wyeomyia

Wyeomyia smithii (Coq.). Pitcher-plant mosquito.

Breeds only in the water in the leaves of pitcher plants (*Sarracenia purpurea L.*) growing in bogs. Winters as larva, frozen in the solid ice cores in the leaves. Two to four irregular, overlapping generations each year. Eggs laid singly or in small, loose groups on the surface of the water or on the sides of the leaves above the water. Larvæ seldom come to the surface. Females do not bite. The smallest mosquito in New Hampshire.

Dublin, Aug. (H.G.D.); Durham, Aug. 28, Sept. 4. Larvæ of different sizes have been found nearly every month of the year around Durham.

Genus Psorophora

Psorophora ciliata (Fabr.), Giant mosquito.

Breeds in temporary rain puddles. Winter passed in the egg stage, some of the eggs hatching whenever the pools are filled with rain. Eggs laid singly in depressions likely to be filled by rains. Larval period short. Larva predaceous, feeding on the larvæ of other mosquitoes, which are seized with the modified mouth brushes. Female a severe biter. Our largest New Hampshire mosquito.

North Hampton, Sept. 11

Genus Aedes

The winter is passed in the egg stage. Eggs laid singly or in small, loose groups, usually on sod, mud, dead leaves, etc. in depressions or moist areas that are likely to be filled with water. Eggs usually hatch

in the spring when they are covered with water. Breed in all sorts of temporary or semi-permanent pools. Air-tube of the larva short or medium in length. The majority have one generation each year, the adults appearing in the spring and the females living for two months or more. The salt-marsh, tree-hole, and rock-pool mosquitoes have more than one generation. Adults are mostly evening or night flyers, but some are active during the day. All the females will bite and suck blood. Adults generally occur in woods, but some are found in the open and a few enter houses readily. This genus contains over half of the species found in New Hampshire, and includes our most common mosquitoes.

Aedes trivittatus (Coq.). Three-striped mosquito.

Breeds in the flood-pools of rivers, also in rain-filled ground pools. Has been found in Maine and Massachusetts, and certainly occurs in the state.

Aedes intrudens Dyar

Breeds very early in ground pools formed by melted snow. Adults disappear by July. Differs from other woods mosquitoes in that it enters houses freely.

Dublin, May 23 (E. C. Stowell); Jaffrey, June 4 (C.W.J.); Glen House, June 14, (C.W.J.); Bretton Woods, June 25, June 28 (C.W.J.); Durham, May 3.

Aedes diantæus H. D. & K.

Breeds in early ground pools, especially in spruce bogs. A rare species found in dark woods.

Dublin, May and June (A.B.); Jaffrey, June 9 (C.W.J.)

Aedes aurifer (Coq.)

Breeds in temporary pools in spring, especially in open bogs and swamps. Rare.

Center Harbor, July 22 (H.G.D.); Dublin, June (A.B.)

Aedes hirsuteron (Theo.)

Breeds in flood pools of rivers and sometimes in early woodland pools.

Dublin, June (A.B.); Hanover, July 8 (C.W.J.)

Aedes punctor (Kirby)

Breeds in early pools, especially mossy woodland pools and bog pools. Females long lived.

Dublin, May (A.B.); Hanover, July 4 (C.W.J.)

Aedes implacabilis (Walker)

Breeds in early, cold, woodland pools.

Dublin, May and June (A.B.)

Aedes impiger (Walker)

Larvæ in the earliest spring pools. Not common

Franconia; White Mountains; —records from Johnson.

Aedes communis (DeG.) Black-legged mosquito.

Larvæ in the early woodland pools. This is our most common black-legged woods mosquito.

Dublin, May (A.B.); Jaffrey, June 4-15 (C.W.J.); Mount Washington (A. T. Slosson); White Mountains (H. K. Morrison); Glen House, June 14

(C.W.J.); Intervale, May 20 (G. M. Allen); Rye, May 15, May 28, June 2, July 6; Durham, May 17.

Aedes trichurus (Dyar)

Breeds in early pools at edges of grassy swamps, in ditches along roads; and in woods-pools. Common.

Dublin, May (A.B.); Pike, May 25 (A. D. Hopkins); Hampton, May 21 (S. A. Shaw); Durham, May 1, May 10, May 17.

Aedes dorsalis (Meigen)

Breeds in pools in the salt marshes along the coast. Several generations. Usually rare, but occasionally occurs in great numbers. Not yet found in the state.

Aedes canadensis (Theo.) Woodland-pool mosquito

Breeds in woodland pools, also in pasture pools and roadside ditches. All the overwintering eggs do not hatch when first covered with water, but part of them hatch at intervals during the summer when heavy rains fill the pools.

Center Harbor, May 16 (H.G.D.); Dublin, May and June (A.B.); Hanover, July 8 (C.W.J.); Bretton Woods, June 24, 28 (C.W.J.); Durham, May 6, larvæ.

Aedes excrucians (Walker). Brown-striped woods mosquito. ....

Breeds in early pools at edges of grassy swamps, occasionally in woodland pools. Females long lived. Common.

Dublin (A.B.); Rye, May 18, June 11; Durham, May 17, May 19, May 30.

Aedes stimulans (Walker). Brown woods mosquito.

Breeds in flood pools of rivers or in open ground pools.

Jaffrey, June 11 (C.W.J.); Johnson also reports it from Hampton; Durham, May 3.

Aedes cantator (Coq.). Brown salt-marsh mosquito.

Breeds in the pools on the salt marshes along the coast. Larvæ in salt and fresh water, but prefer the less salty pools. Several generations, a brood developing whenever the pools are filled by extra high tides or heavy rains. The adults may fly considerable distances and be annoying far from their breeding places. Enters houses freely.

Hampton, June 9—Sept. 5 (S. A. Shaw); Rye, June 2—Oct. 6.

Aedes fitchii (Felt & Young)

Breeds in early spring pools, especially grassy edges of swamps. Females long lived.

Dublin (A.B.); Hanover, July 5 (C.W.J.)

Aedes atropalpus (Coq.) Rock-pool mosquito.

Breeds in pot-holes and rock-holes along streams and lakes. Several generations, the number depending on the filling of the rock pools by rains, high water or waves. Eggs laid on the sides of the pool attached to the rock above the water level. Local in distribution.

Center Harbor, Sept. 17 (H.G.D.); White Mountains (H. K. Morrison); Bretton Woods, June 26 (C.W.J.); Raymond, Aug. 25, larvæ.

Aedes sollicitans (Walker). White-marked salt-marsh mosquito

Breeds in the pools in the salt marsh along the coast. Several generations, the number depending on the filling of the pools by extra high tides or heavy rains. The saltier pools are preferred, but larvæ can live in water ranging from fresh to that 25% more salt than sea water. Females fly long distances, flights of forty miles being on record. Females severe biters both by day and night, and enter houses freely.

Hampton, June 26—Aug. 13 (S. A. Shaw); Rye and North Hampton, June 11—Oct. 22; Durham, June 15—Aug. 25; Isles of Shoals, July 27—Aug. 4; Epping, Aug. 22.

Aedes tæniorhynchus (Wied.). Small salt-marsh mosquito.

Breeds in salt or fresh water along the seacoast, preferring water only slightly salty. Several generations. Not yet collected in the state.

Aedes triseriatus (Say). Tree-hole mosquito.

Breeds in the water in holes in the trunks of trees. Eggs laid on the sides of the cavity, just above the water line. Probably several generations. Local in distribution.

Center Harbor, June 24 (H.G.D.); Durham, Sept. 21.

Aedes vexans (Meigen). Swamp mosquito.

Breeds in many temporary ground pools, particularly open, grassy swamps. Overwintering eggs do not all hatch at once, but some of them hatch each time the pool is filled by rains. A common species.

Center Harbor, Aug. 22 (H.G.D.); Rye, June 1—Aug. 5.

Aedes cinereus Meigen. Little smoky mosquito

Breeds in various temporary ground pools. All over-wintering eggs do not hatch in the spring, some hatching each time the pools are filled by heavy rains throughout the summer. Larva slow in development.

Center Harbor, Aug. 5 (H.G.D.); Dublin, May (A.B.)

Genus Culicella

Culicella melanura (Coq.)

Breeds in cold springs or permanent bog pools. Winter passed in the larval stage. Rare and local in distribution. No records of its biting habits. Eggs apparently laid singly on surface of the water. Several generations.

Center Harbor, Aug. 19 (H.G.D.); Durham, Sept. 21.

Culicella dyari (Coq.)

Breeds in cold spring or bog pools. Apparently one generation from overwintering eggs, but little is known of its life history. No records of its biting. Rare and local in distribution.

Center Harbor, May (H.G.D.); Dublin (A.B.)

Culicella inornata (Williston)

Breeds in permanent stagnant ground pools. Winters as an adult. Eggs laid in rafts on the surface of the water. Several broods. Females seldom bite humans, preferring the larger mammals. Not yet collected in the state.

Culicella impatiens (Walker)

Breeds in permanent forest-pools and springs. Winters as an adult.

Eggs laid in rafts on the surface of the water. As far as known, but one generation occurs. Females not troublesome biters. Rare.

Monadnock, May 11 (A. H. Thayer); White Mountains (H. K. Morrison.)

Genus Mansonia

Mansonia perturbans (Walker). Irritating mosquito

Breeds in permanent grassy swamps or margins of ponds. Eggs laid in rafts on the surface of the water. Winter spent as a half-grown larva. One generation. The larvæ do not come to the surface to breathe, but attach themselves to the roots of sedges by means of their pointed air-tubes and obtain air from the plant tissues. The pupæ attach and breathe in a similar manner by means of their breathing-trumpets. The females will fly several miles, are severe biters and enter houses freely.

Center Harbor, July 19, Aug. (H.G.D.)

Genus Culex

Winters as adult females. Eggs laid in rafts on the surface of the water. Several generations each year. The larvæ have long air-tubes.

Culex territans Walker. White-dotted mosquito.

Breeds in dirty ground pools, stagnant ditches and artificial receptacles as water barrels. A semi-domesticated species often breeding around houses and entering freely. An annoying biter.

Center Harbor, Aug. 22 (H.G.D.); Johnson reports it from the Mt. Monadnock region.

Culex pipiens Linn. House mosquito.

This is a domesticated species rarely found far from human habitations, and often the only species breeding in cities. Breeds primarily in water in artificial receptacles such as barrels, buckets, tin cans and bottles, also in sewer catch-basins, obstructed roof gutters and sometimes in dirty ditches and ground pools. The larvæ will live in foul or polluted water. Enters houses freely and is a troublesome biter at night. Often rare in rural districts and villages.

Durham, (H.G.D.)

Culex apicalis Adams

Breeds in grassy pools and swamps and edges of ponds. Females feed on the blood of cold-blooded animals such as frogs, and never attack humans.

Center Harbor, July 16 (H.G.D.)

Genus Uranotaenia

Uranotænia sapphirina (O.-S.). Sapphire-lined mosquito

Breeds in stagnant, vegetation-filled, permanent ponds. Probably winters as an adult female. Eggs laid in a raft on the surface of the water. Several generations. A rare species that seldom bites.

Center Harbor, July 27 (H.G.D.); Dublin, Aug. (H.G.D.)

Genus Anopheles

Winters as adult females. Eggs laid singly or in loose groups on the surface of the water. Each egg is partly surrounded at its middle with a float, an air-filled structure which prevents it from sinking to the bottom. Several generations each year. The larvæ have very short air-tubes and are surface feeders, floating with the body parallel to the surface-film. The species of this genus are carriers of malaria fever.

Anopheles punctipennis (Say). Mottled-wing anopheles.

Breeds in swampy areas, ground pools of various kinds and even in transient rain puddles. Females bite at dusk. Not considered a dangerous malarial carrier. Our most common *Anopheles*, often found in houses during the winter.

Center Harbor, July 17 (H.G.D.); Dublin, (A.B.); Monadnock, May 1 (A. H. Thayer); Intervale, Aug. 18 (G. M. Allen); Hampton (S. A. Shaw); Durham, Feb. 11, April 10, 26, May 1, Sept. 15.

Anopheles maculipennis Meigen

Breeds in small, open, permanent pools containing algæ. A dangerous malaria carrier. Not yet collected in the state.

Anopheles quadrimaculatus Say. Malaria mosquito

Breeds in permanent ground pools and ponds containing algæ, also in swamps, backwaters of rivers and sometimes in the brackish water of salt-marsh pools. A very dangerous malaria carrier.

Center Harbor, Aug. 1 (H.G.D.); Berlin Falls, Aug. 9 (F. G. Sanborn). Johnson reports it from Hampton and the Mt. Monadnock district.

Anopheles walkeri Theo.

Breeds in permanent water containing much vegetation. A rare species which has not been shown to carry malaria. Not yet found in state.

SUBFAMILY CORETHRINAE. The Non-biting Mosquitoes

This includes the species whose mouthparts form a short beak, not fitted for biting or sucking blood. The larvæ are predaceous, feeding on other mosquito larvæ, which are seized with the modified antennæ. They breed in cold, shaded, woodland pools.

Genus Corethra

Corethra cinctipes Coq.

Franconia (A. T. Slosson); Hampton, June 13 (S. A. Shaw)

Corethra culiciformis (De G.)

Franconia (A. T. Slosson); Dublin (A. B.); Durham, May 28.

Genus Chaoborus

Chaoborus albipes (Johannsen)

Hampton, June 27 (S. A. Shaw)

Chaoborus crystallina (De G.)

Mount Washington (A. T. Slosson)

Chaoborus punctipennis Say

Reported by Johnson for the White Mountain and Lake Winnipesaukee areas.

Chaoborus trivittatus Loew

Center Harbor (H.G.D.); Hampton, April 19-21 (S. A. Shaw); Durham, May 6.

Genus Eucorethra

Eucorethra underwoodi Underwood

Dublin, May 15 (A.B.); Crawfords (A. T. Slosson)

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